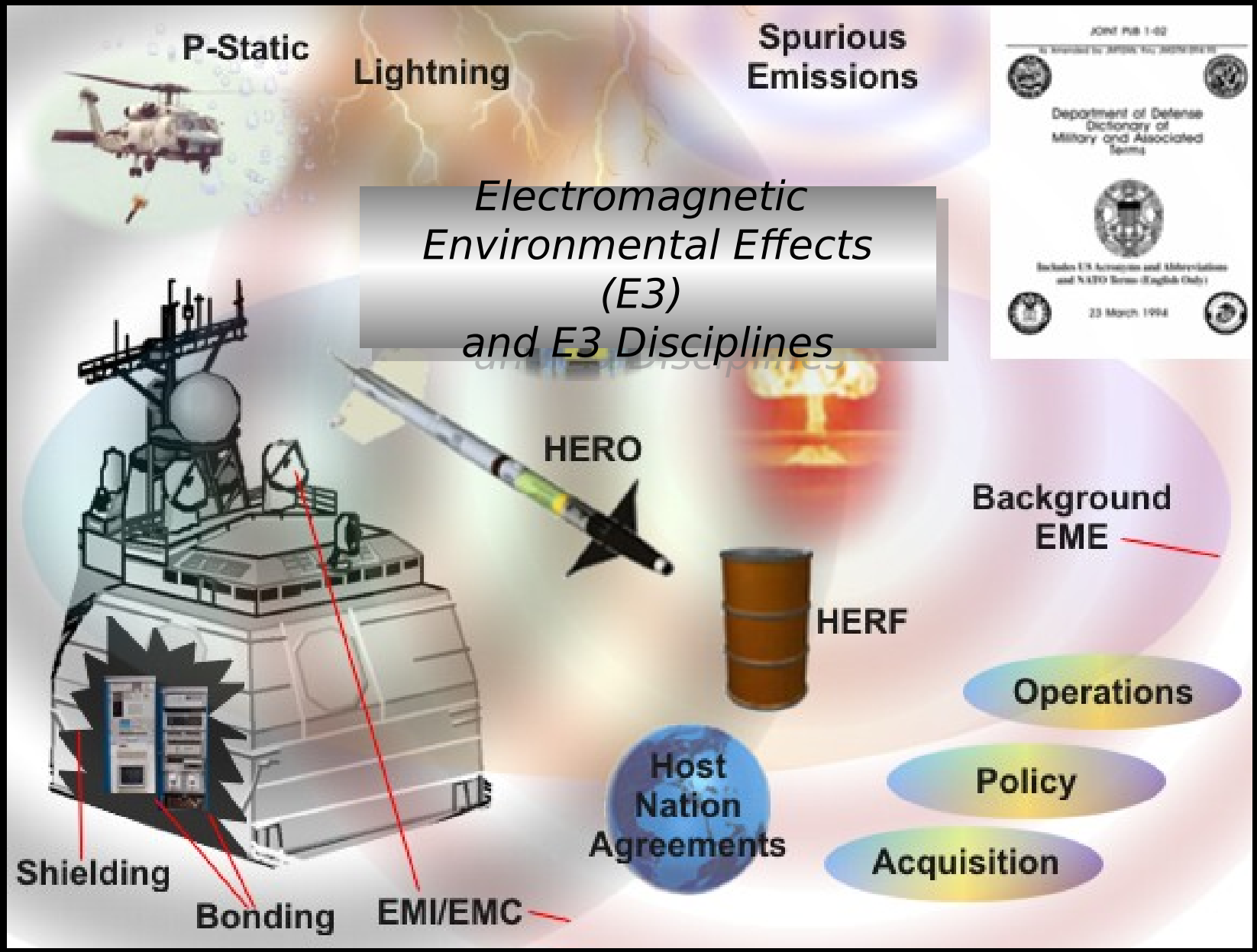
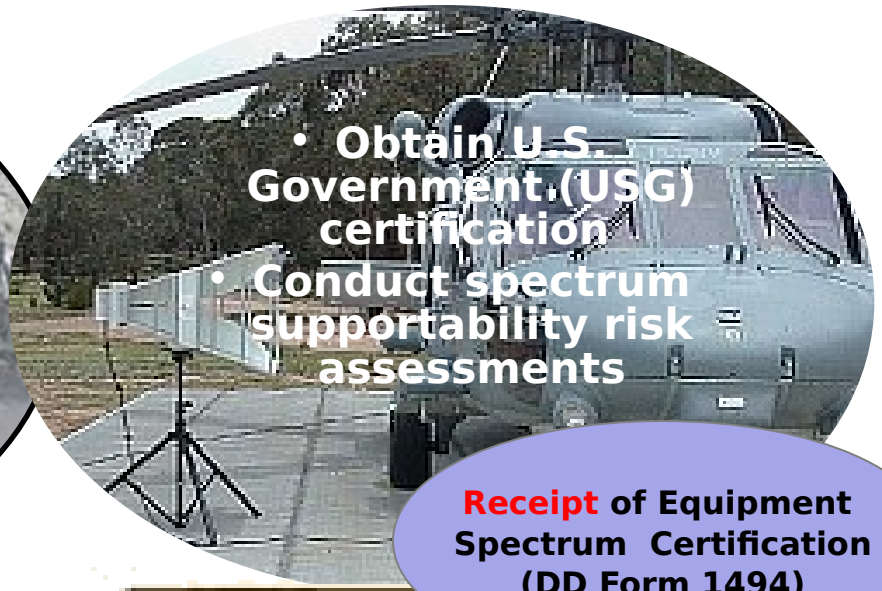
Joint Spectrum Center
Research, Development, and Acquisition (RD&A) Engineering Division
j5@jsc.mil

Electromagnetic Environmental Effects (E3) and Spectrum Supportability (SS) for Acquisition Professionals


P-Static
Lightning
Spurious Emissions
Electromagnetic Environmental Effects (E3) and E3 Disciplines
HERO
HERF
Background EME
Operations
Policy
Acquisition
Host Nation Agreements
Shielding
Bonding
EMI/EMC

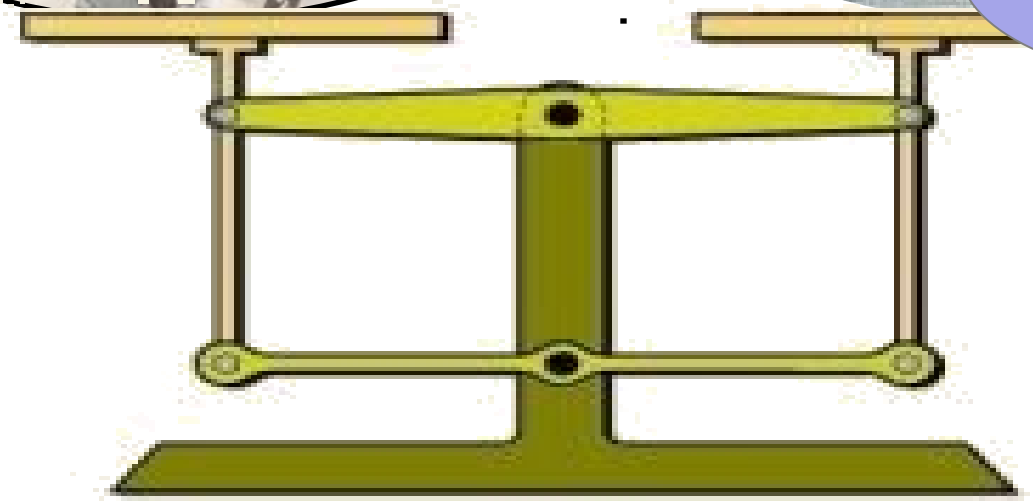
DISA Spectrum Supportability (SS)

- Ensure the U.S. warfighter has sufficient spectrum access to support military capabilities
- Pursue spectrum-efficient technologies



- Obtain U.S. Government (USG) certification
- Conduct spectrum supportability risk assessments

Receipt of Equipment Spectrum Certification (DD Form 1494)



Equipment Life Cycle Spectrum and E3 Concerns

Chip

ESD

Circuit Board

EMC/EMI
ESD

Equipment

EMC/EMI
EMV
HERP
Spectrum
Cert

Suite

EMC/EMI
EMV
HERP
HERO
HERF
Lightning
EMP
P-Static

Platform

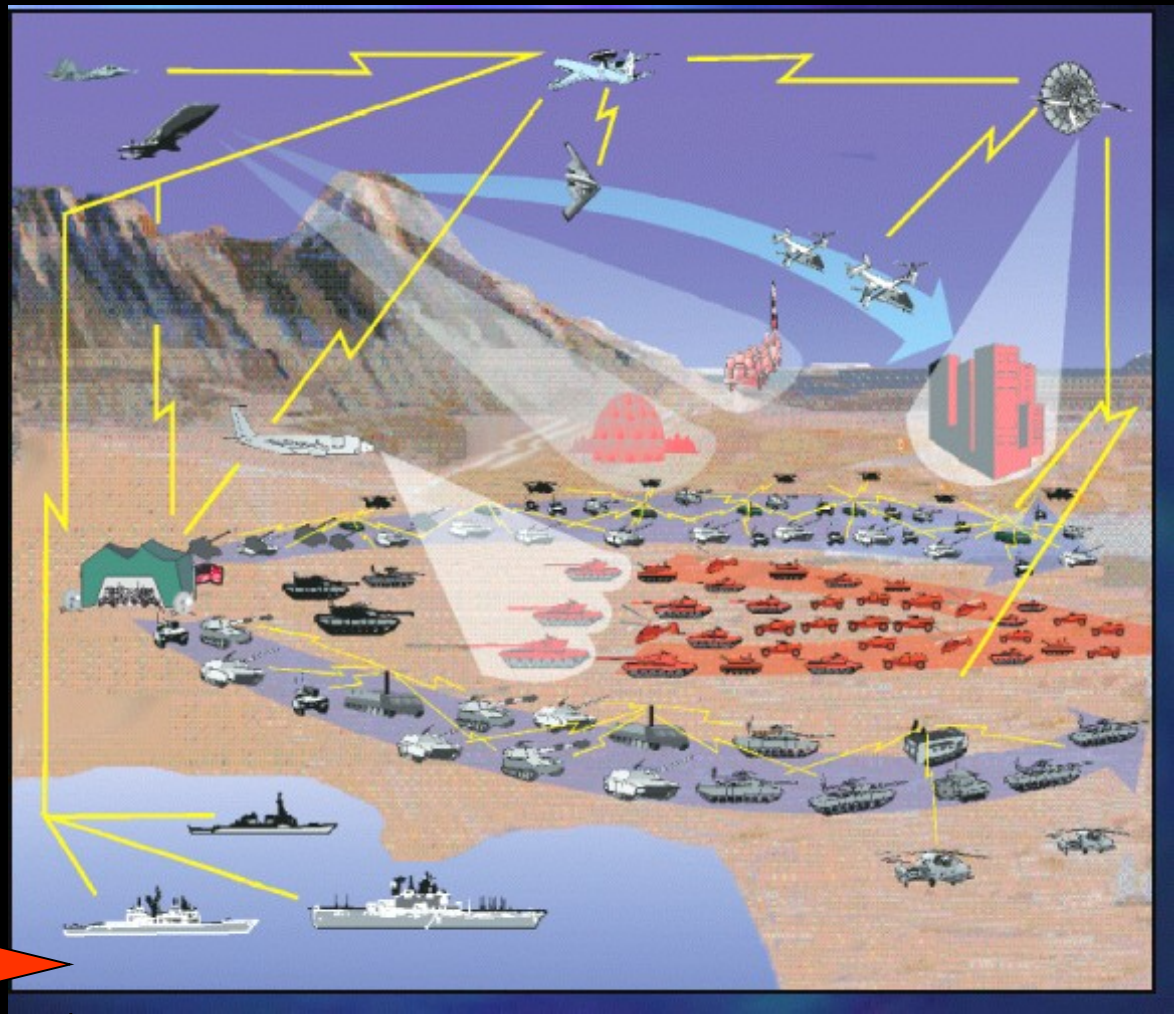
EMC/EMI
EMV
HERP
HERO

Multiple

EMC/EMI
EMV
HERP
HERO
Frequency
Planning

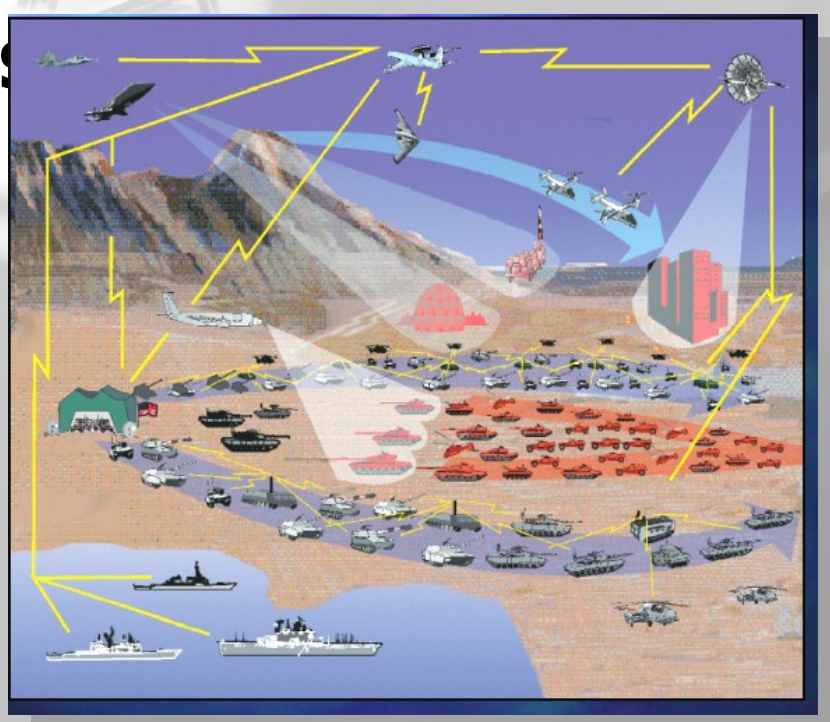
Today's Complex Battlespace

"In today's complex and electromagnetically dense battlefields…the Commander who controls the electromagnetic spectrum, controls the outcome"…



E3 Tutorial

- Composition
- Definitions
- EM Environments



Electromagnetic Radiation 101

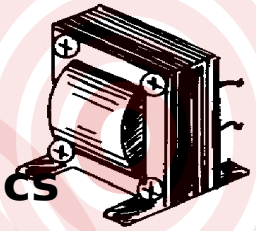
All Electronic Equipment Radiates Energy - Some Intentional...

Some Intentional Radiators:

- Broadcast and Cell Towers
- Radars
- Cellular Phones

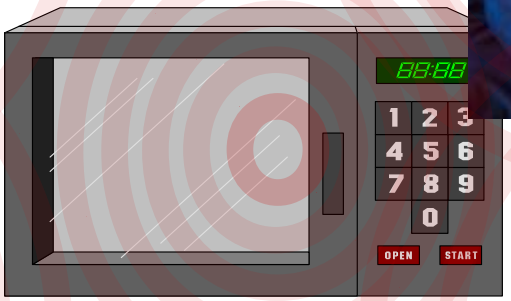
Electromagnetic Radiation 101

...and Some Unintentional



Motor Components

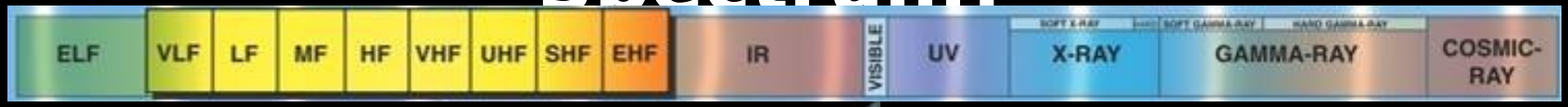
Powerful Electronics

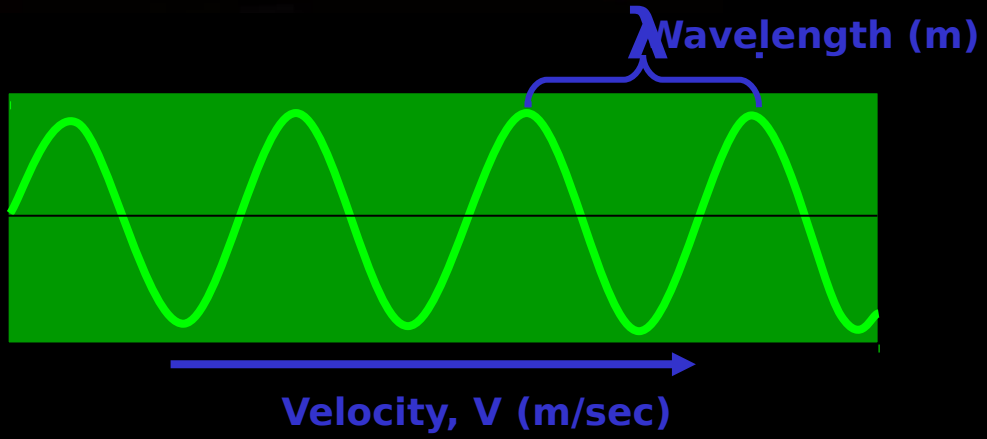


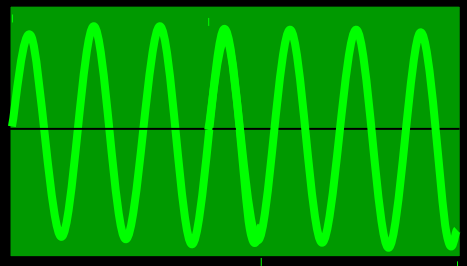
Fluorescent Lights

Arc Welders

What is the Radio Frequency Spectrum?







$$\text{Frequency} = f = \frac{V}{\lambda} \quad \text{(Hertz)}$$

Electromagnetic Spectrum (EMS) from DoDD 4650.01

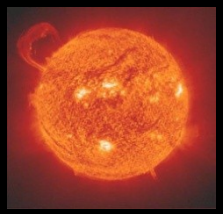
DoDI 4650.01 defines EMS as the range of frequencies of EM radiation from zero to infinity. For the purposes of this Instruction, “electromagnetic spectrum” shall be defined to be the range of frequencies of EM radiation that has been allocated for specified services under the U.S. and international tables of frequency allocation, together with the EM spectrum outside the allocated frequency range where use of unallocated frequencies could cause harmful interference with the operation of any services within the allocated frequency range. The terms “electromagnetic spectrum,” “radio frequency spectrum,” and “spectrum” shall be synonymous.

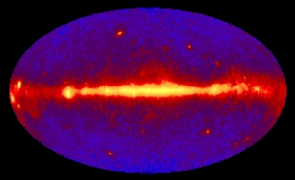
The Spectrum: What is it?

Hz 10^0 10^2 10^4 10^6 10^8 10^{10} 10^{12} 10^{14} 10^{16} 10^{18} 10^{20} 10^{22} 10^{24}

ELF SLF VF VLF LF MF HF VHF UHF

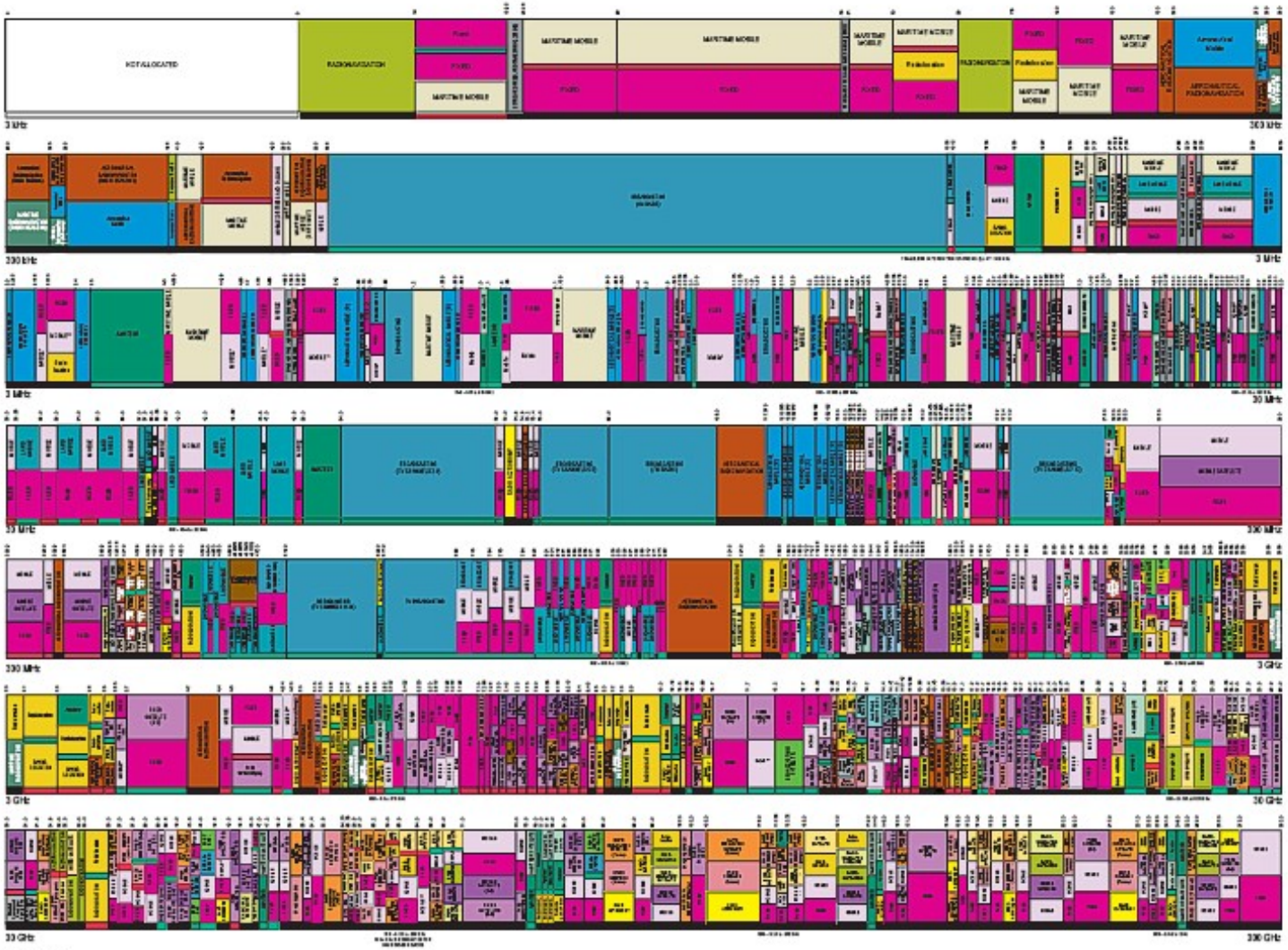
Long Radio Waves | Radio | Microwave | IR | UV | X-Rays | Gamma Rays





UNITED STATES FREQUENCY ALLOCATIONS

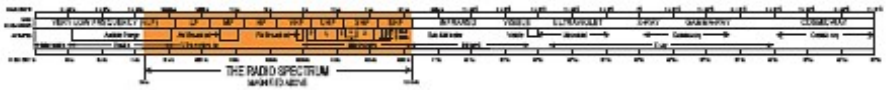
THE RADIO SPECTRUM



RADIO SERVICES COLOR LEGEND

ACTIVITY CODE

ALLOCATION USAGE DESIGNATION



U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

© October 2003

- **Spectrum Management Is Complex:**
  - **Frequency bands carved up into "segments"**
  - **Services often stacked in same band**
- **DoD Has *VERY* Few Exclusive allocations**
- **By international law, countries can allow or disallow any spectrum use within their borders**
- **No Internationally recognized spectrum reserved exclusively for military use**

Electromagnetic Spectrum Management (SM)

Joint Publication 1-02:

“Planning, coordinating, and managing joint use of the electromagnetic spectrum through the operational, engineering, and administrative procedures. The objective is to enable electronic systems to perform their functions in the intended environment without causing or suffering unacceptable interference.”

Use

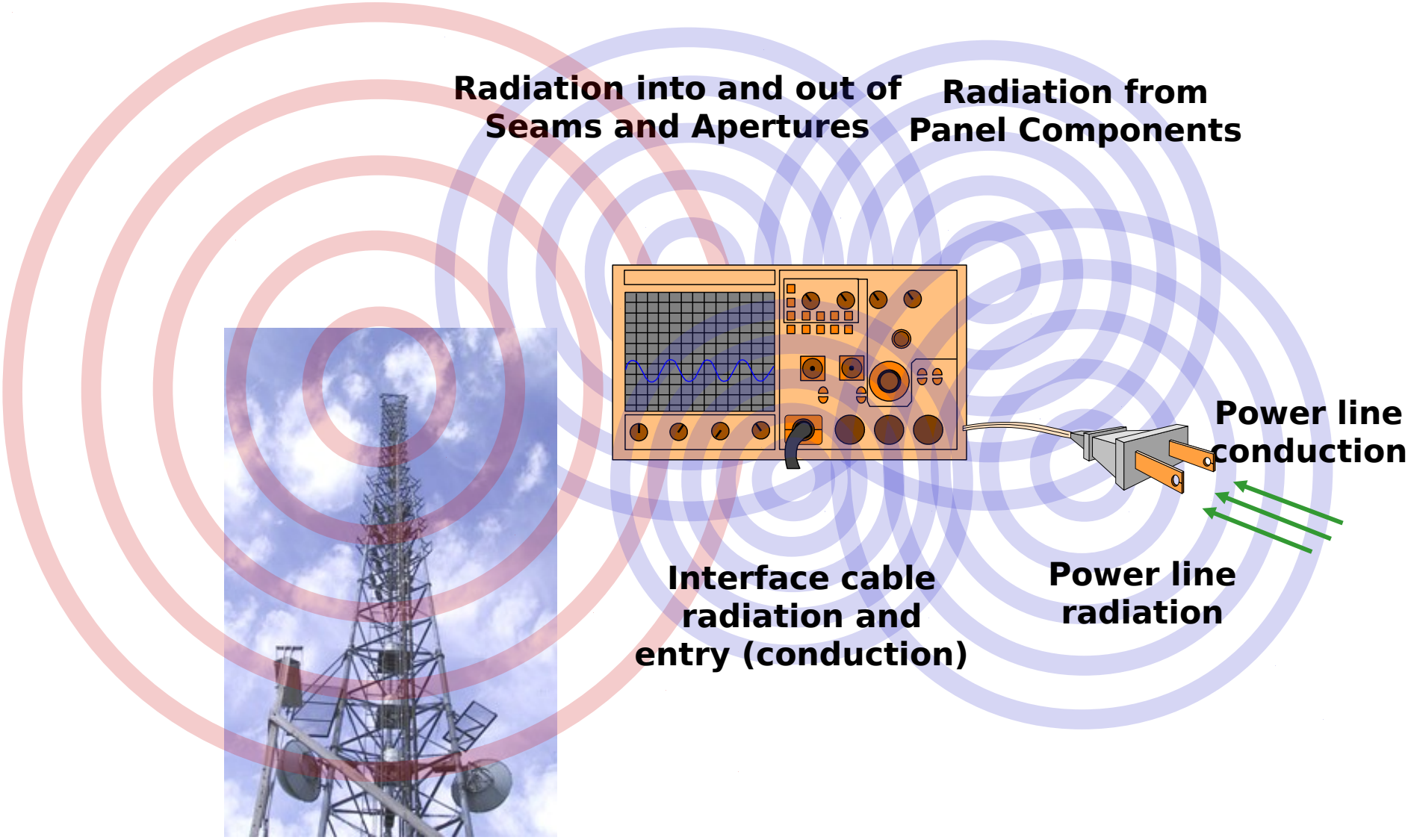
Coordination

EMI EMC

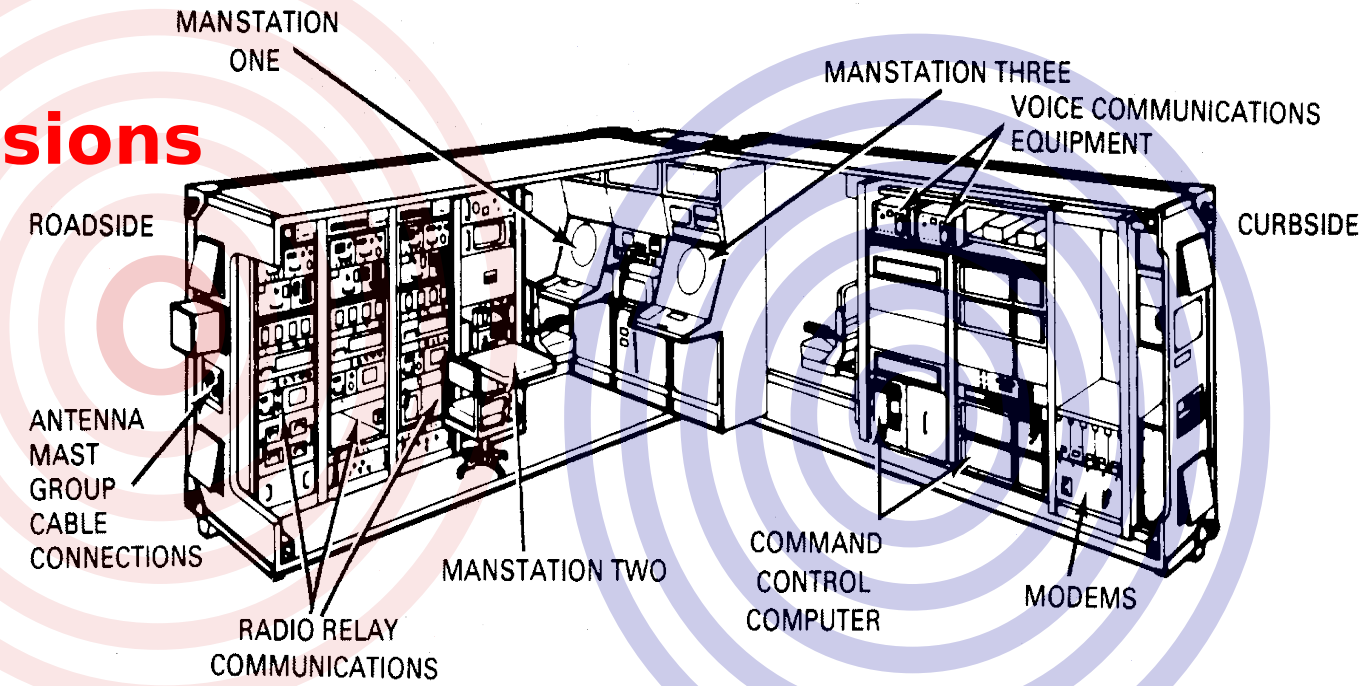
Planning

Electromagnetic Interference

Emanations to and from Equipment



Electromagnetic Interference (EMI)



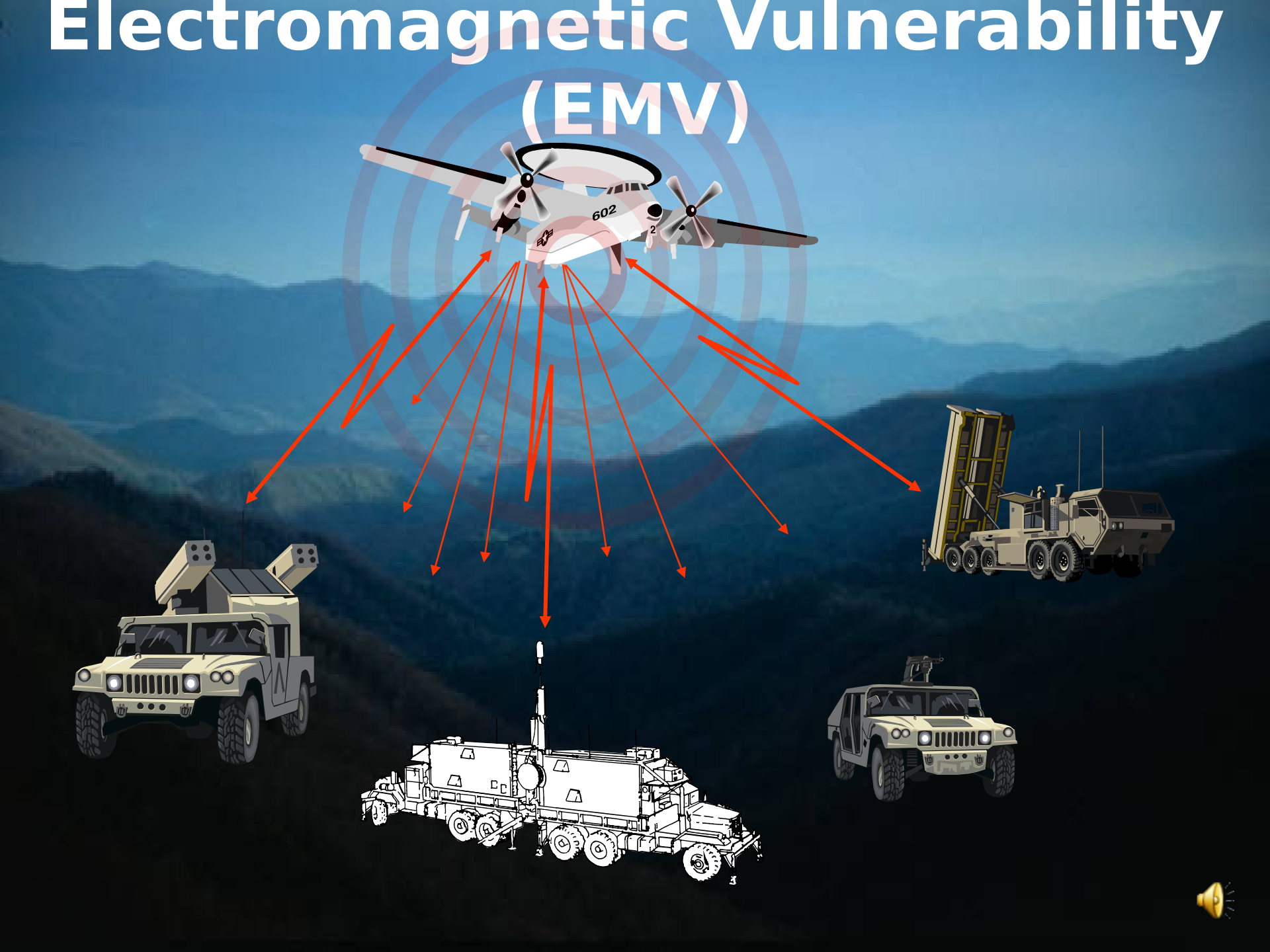
Emissions

Susceptibility

Electromagnetic Compatibility (EMC)

The ability of systems, equipment, and devices that utilize the electromagnetic spectrum to operate in their intended operational environments without suffering unacceptable degradation or causing unintentional degradation because of electromagnetic radiation or response.

Electromagnetic Vulnerability (EMV)



Electromagnetic Pulse (EMP)

The electromagnetic radiation from a nuclear explosion caused by Compton-recoil electrons and photoelectrons from photons scattered in the materials of the nuclear device or in a surrounding medium.

Lightning

- indirect
- direct
- cloud-to-ground lightning
- intra-cloud lightning
- inter-cloud lightning
- ball lightning
- heat lightning
- bead lightning
- sheet lightning
- silent lightning
- black lightning
- ribbon lightning
- tubular lightning
- meandering lightning
- cloud-to-air lightning
- stratospheric lightning
- red sprites
- blue jets
- elves

Lightning

- Lightning Direct Effects
- Lightning Indirect Effects

Electromagnetic Radiation Hazards

HERP

HERF

HERO

Hazards Of Electromagnetic Radiation To Personnel - HERP

HERP

- **Based on DoDI 6055.11**
  - **Specific Absorption Rate (SAR)**
  - **Time in EM Field**
  - **Frequency of EM Field**
  - **Intensity of EM Field**

Hazards Of Electromagnetic Radiation To Volatile Materials (Fuel) - HERF

HERF

- Ignition of Fuel Vapors by RF Induced Arcs
  - Flammable Fuel-air Mixture Must be Present
  - Arc Must be of Sufficient Energy
  - Modern Aircraft Fuel Significantly Reduces Susceptibility

Hazards Of Electromagnetic Radiation To Ordnance - HERO

HERO

- **Ordnance elements are potentially susceptible to high EMEs**
- **Danger is premature actuation of various electrically initiated devices such as:**
  - **Burn Wires And Fuzible Links**
  - **Slapper Detonators**
  - **Exploding Foil Initiators**
  - **Laser Initiators**
  - **Electronic Safe And Arm Device (ESAD)**

Electrostatic Discharge (ESD)

A transfer of electrostatic charge between objects at different potentials caused by direct contact or induced by electrostatic fields.

Human Body

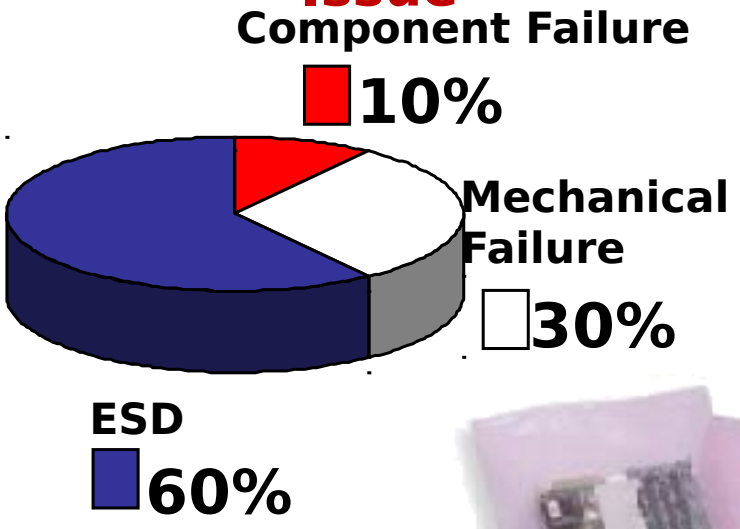
Voltage Output Ranges From 5-35 kV

Mid-air Refueling and Vertrep

Static Charges Can Reach 300 kV

Industrial Field Failures

ESD Prevention is a big Issue

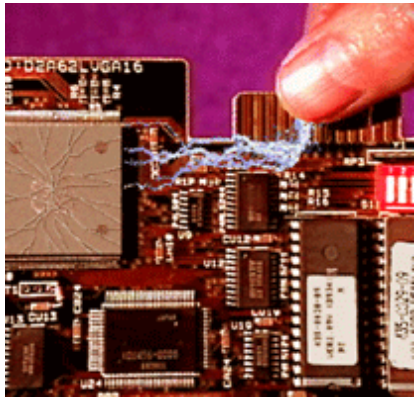


Source: *Semiconductor Reliability New*

- January 1967 Apollo 1 Disaster
- $500,000,000 Problem in 1984
- 4,000,000,000 Problem in 1994
- $8,000,000,000 Estimate in 2004
- ISO 20.20 Implemented in 2001

Types of ESD Failures

- Catastrophic
- Intermittent
- Latent



According to the Petroleum Equipment Institute, in the last two years, more than 150 people have been the victim of static electricity fires while pumping gas.

The fuel nozzle is inserted into the gas tank pipe and the driver then re-enters their vehicle. The driver gets out without properly grounding and grabs the pump nozzle, igniting the gas vapors via a static charge.

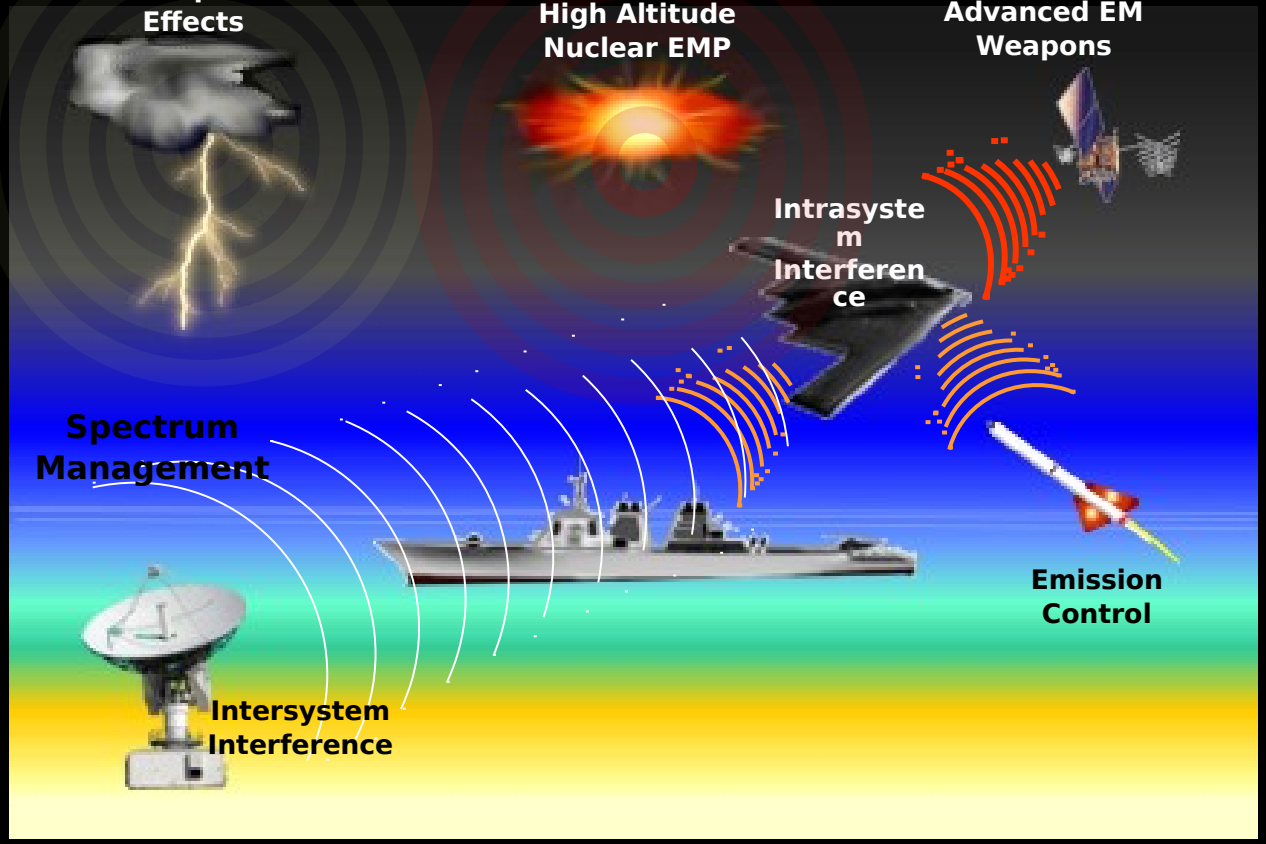
Little-Known Danger Could Cause Serious Injuries – KNBC TV LA

UPDATED: 2:01 p.m. PST November 5, 2002

Precipitation Static (P-static)

- **Electrostatic Charge Build-up**
  - **Fluid Or Air Flow**
- **Special Emphasis**
  - **Electronic Systems Sensitivity**
  - **Composite Materials**

Electromagnetic Environmental Effects (E3)



- **Variety of sources**
  - Natural
  - Manmade
    - Unintentional
    - Intentional
- **Manifestations**
  - Aural (noise)
  - Visual (disturbed displays)
  - Physical (uncommanded response)
- **Impact**
  - Mild → Catastrophic

- **EMI Level Increases Proportionally With Mission Stress !**
- **Peace-time Complacency Could Result in Wartime Fatalities !**
- **Only Difference Between a Transmitter And a Jammer is Intent !**